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Vol. IV

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CONTRACT NAS9-9334

SOLID STATE SEQUENCER SYSTEM
PHASE II.

SUMMARY REPORT

MARCH 1971

APPENDIX C

Reliability Analysis

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

MARTIN MARIETTA CORPORATION
P. O. Box 179
Denver, Colorado 80201

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RELIABILITY ANALYSIS

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RELIABILITY ANALYSIS

This section contains the reliability prediction and failure modes and effects analysis (FMEA) for the Engineering Model Sequencer. It is submitted in response to paragraphs 4.2 and 4.3 of the Reliability Plan to demonstrate the reliability requirement of 0.999,999 as given in paragraph 3.1.4 of the Statement of Work.

1.0 RELIABILITY ANALYSIS GROUND RULES AND ASSUMPTIONS

Since reliability is determined from the expression

$$R = e^{-\lambda t}$$

where t is the mission time, appropriate assumptions must be made regarding total mission time, checkout time, dormant time, and the various modes of system operation during these various phases of the total mission.

The total mission time assumed is 66 days, or 1584 hours. This includes 60 days of flight time and 6 days of checkout time.

Of the 6 days of checkout time, it is estimated that power will be off for 33 hours and during this time the circuits will be dormant. A factor of 0.1 has been applied to the failure rates during this dormant period.

Many circuits, such as the Core Transistor Logic elements (CTLs), draw no current for long periods of time, even though power is applied. A factor of 0.25 has been applied to the failure rate of these circuits during this time. This mode of operation is called "non-operative" in the charts which follow. This also applies to the output switch circuits. Many of these circuits draw current (defined as the "operative" mode) for only 10 seconds or less during the entire mission. Some CTLs operate for as little as 10 milliseconds.

Many of the sequencer circuits operate on switched power. These circuits are in the dormant mode for all except 10 seconds of the 66 days. This mode of operation does not apply to CTLs and other magnetic logic circuits, but does apply to many ICs and conventional discrete component circuits.

The de-rating factors of 0.1 for the dormant mode and 0.25 for the non-operating mode were taken from "Electronics and Parts Reliability", RADC-TR-67-307, July 1967.

These ground rules are summarized in Table 1.

	CONSTANT POWER			SWITCHED POWER		
	OPERATE TIME X 1.0	DORMANT TIME X 0.10	NON-OP TIME X 0.25	OPERATE TIME X 1.0	DORMANT TIME X 0.10	NON-OP TIME X 0.25
CTLs and Output Circuits	2.78×10^{-6} (10^{-2} Seconds)	3.3	388	N/A	N/A	N/A
ICs and Discretes	1551	3.3	0	2.78×10^{-3} (10 Seconds)	158.4	0

TABLE 1

SUMMARY OF OPERATING MODES, OPERATING PERIODS, AND DE-RATING FACTORS USED IN RELIABILITY ANALYSIS

2.0 RELIABILITY APPROXIMATIONS

Reliability is given by

$$R = e^{-\lambda t}$$

Where t is mission time and

$$\lambda = \sum_i N_i K_i G_{fri}$$

is the failure rate of the system, subsystem, or set of circuits included in the summation of the set of "i" components. G_{fri} is the generic failure rate of the "ith" component. As noted in Paragraph 1.0, the operating factor K_i has been applied directly to the time duration of various mission phases.

The unreliability is given by:

$$Q = 1 - R = 1 - e^{-\lambda t}$$

and if λt is less than 0.001 this is very closely approximated by

$$Q = \lambda t$$

This approximation is used throughout this analysis.

3.0 TYPES OF REDUNDANCY

The complete sequencer system is a parallel channel system, so that an output is possible even though one channel has failed. The unreliability of the complete system is then given by:

$$Q_s = Q_c^2$$

Where Q_c is the reliability of a single channel. The reliability of the system is then:

$$R_s = 1 - Q_s = 1 - Q_c^2$$

This is the parameter which the SOW requires be 0.999,999 (six nines) or greater.

In addition to the parallel redundancy, each channel consists of two series paths so that a single failure will not produce an inadvertant output. Some areas of the sequencer design, such as the clock, the power supply, and some of the majority voters and

other check circuits, are not series redundant, but in all of these cases, our FMEA and Single Point Failure analysis shows that a single failure will not produce an inadvertant output, so functional series redundancy is maintained throughout the design.

The failure rate of a series pair of elements is the sum of the failure rates of each element of the pair.

Functional parallel redundancy is used in the memory subassembly. The memory stack itself is a functional parallel pair, since normal operation is possible after a single failure has occurred. Thus the unreliability of one-half the stack is first determined and the unreliability for the whole stack is then determined from

$$Q_s = Q_p^2$$

where Q_p is the unreliability of one-half the stack.

The memory assembly includes twelve sense amplifiers and twelve inhibit drivers, and twenty four switch circuits and twenty four drivers. These are all functional parallel redundant, since two or more failures are required to cause a system failure.

The unreliability of these circuits is given by

$$Q_s = \sum_{I=2}^{N} \frac{N!}{I!\,(N-I)!}\, Q_p^{\,I}\, R_p^{\,N-I}$$

The binomial coefficient in each term is the number of ways "N" circuits can have "I" failures and Q_p is the unreliability of one parallel "leg" as shown in Figure 1. For the Q_s we will be dealing with all terms above Q_p^2 will be negligible and R_p is so near unity that the above expression is closely approximated by

$$Q_s = \frac{N!}{2\,(N-2)!}\, Q_p^{\,2}$$

For N = 12, this is:

$$Q_s = 66\, Q_p^{\,2}$$

and for N = 24:

$$Q_s = 276\, Q_p^{\,2}$$

For a triple redundant circuit this reduces to:

$$Q_s = 3\, Q_p^{\,2}.$$

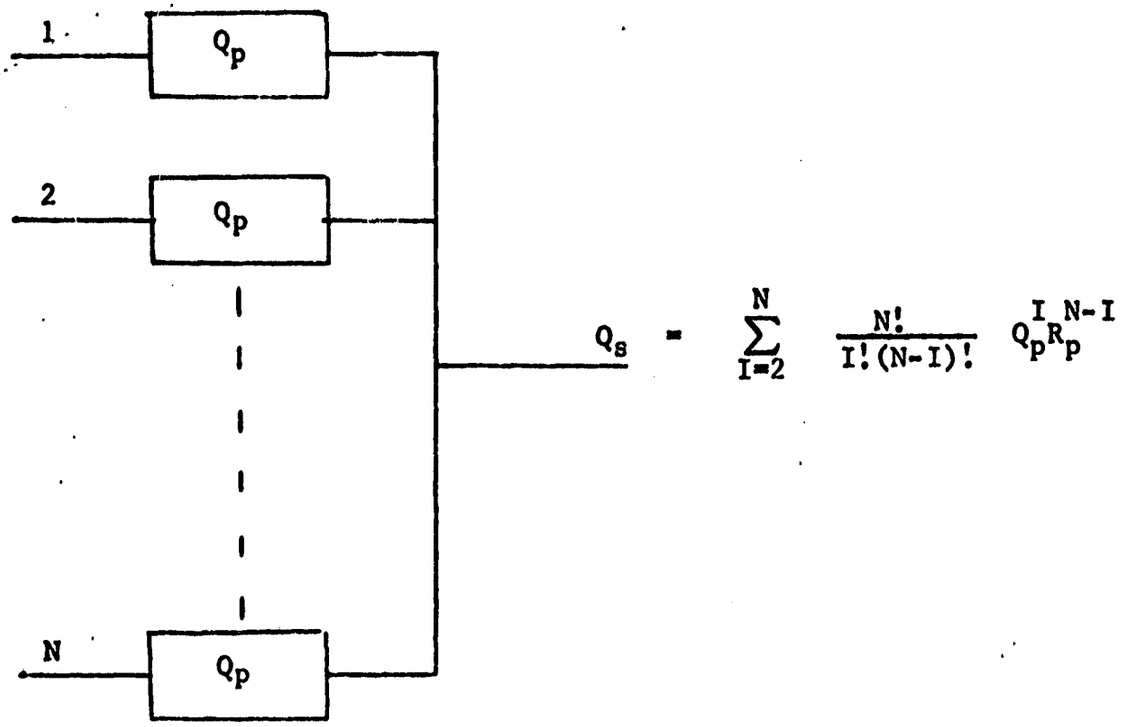


FIGURE 1

FUNCTIONAL PARALLEL REDUNDANT
CIRCUIT WITH "N" LEGS

To summarize, the types of redundancy in the sequencer system are:

1) Series Pairs (SP)
2) Parallel Pairs (PP)
3) Triple Redundancy, Majority Voted (TRMV)
4) Twelve and twenty-four legged functional parallel pairs (FPP)
5) None, but a single failure does not cause an inadvertant output.

Combinations of these types of redundancy also appear in the system, such as series-parallel pairs (SPP) and functional series parallel pairs (FSPP).

4.0 RELIABILITY BLOCK DIAGRAM

A reliability block diagram of a single channel is shown in Figure 2, which also shows a summary of the reliability calculations. Note the very low unreliability of the memory blocks, where some form of functional parallel redundancy or triple redundancy is used in most memory sub-assemblies. Note also that the output channels are treated separately, since a failure in one output does not affect the operation of another channel. For comparison purposes, the reliability of the system with all outputs considered together is also shown in Figure 2.

The outputs from the SMJC represent the worst case and the reliability of these outputs is 0.999,999,942, which exceeds the requirement. The same reliability is obtained for the pyro outputs which use pyro arming circuits (PAC). The reliability for other types of outputs is 0.999,999,945. Even when all outputs are considered together, the reliability os 0.999,999,817, which also exceeds the requirement.

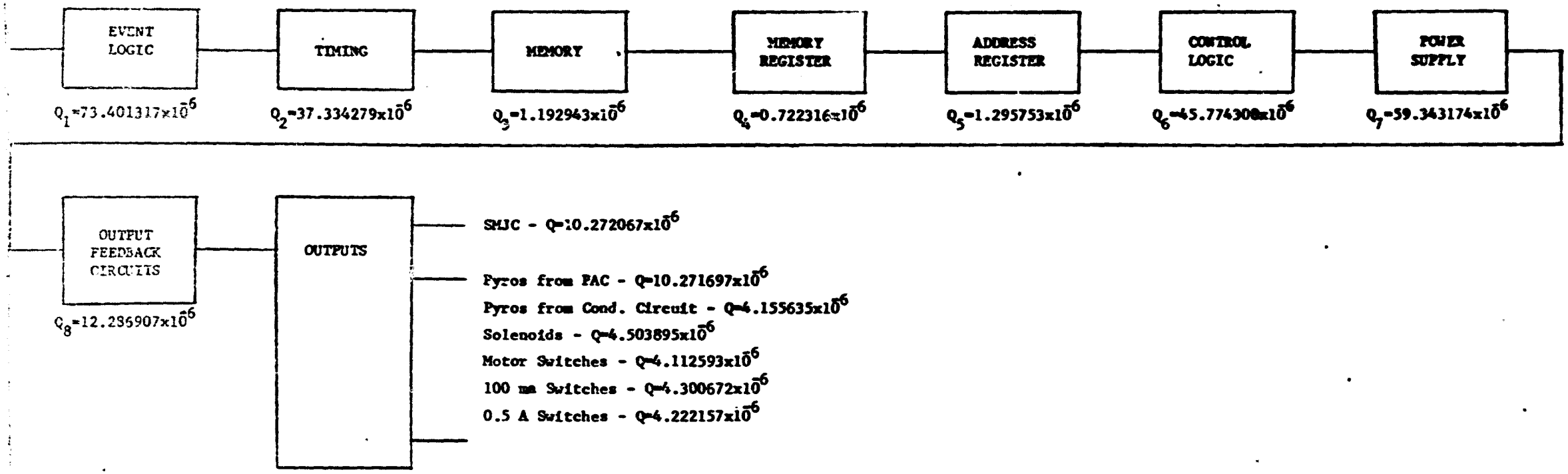
5.0 RELIABILITY CALCULATION DETAILS

The detailed reliability calculations are shown in Tables 2 through 20. These tables are organized as follows. The first table in each group shows the calculation of the unreliability of one of the blocks in the reliability block diagram (Figure 2). This table is followed by a table which shows the detailed calculation of the failure rate of each circuit in that block.

Figure 3 shows the details of the output circuits and the unreliability of each block.

6.0 FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

Changes in the design of the engineering model (Phase II), relative to the breadboard model (Phase I) did not affect the FMEA. Care has continually been taken in the design and fabrication to assure that no single point failure can cause an inadvertant output. Where circuit redundancy does not exist has been noted in the reliability tables and the single point failure situation has been noted. Refer to the Phase I Reliability Analysis for a complete FMEA.



$$\sum_{i=1}^{8} Q_i = 231.350997 \times 10^{-6}$$

SMJC - $Q_c = 241.623064 \times 10^{-6}$; $R_c = 1 - Q_c = 0.999,758,377$; $Q_s = Q_c^2 = 0.058,381,705 \times 10^{-6}$; $R_s = 0.999,999,942$

PAC Pyros - $Q_c = 241.622494 \times 10^{-6}$; $R_c = 1 - Q_c = 0.999,758,378$; $Q_s = Q_c^2 = 0.058,381,429 \times 10^{-6}$; $R_s = 0.999,999,942$

Cond. Pyros.- $Q_c = 235.506632 \times 10^{-6}$; $R_c = 1 - Q_c = 0.999,764,493$; $Q_s = Q_c^2 = 0.055,463,374 \times 10^{-6}$; $R_s = 0.999,999,945$

If all outputs are considered together:

$$Q_c = \sum_{i=1}^{7} + Q_{outputs} + Q_{SMJC} = 219.064090 \times 10^{-6} + 201.278323 \times 10^{-6} + 7.196427 \times 10^{-6} = 427.538840 \times 10^{-6}$$

$R_c = 1 - Q_c = 0.999,572,461$; $Q_s = Q_c^2 = 0.182,789,460 \times 10^{-6}$; $R_s = 1 - Q_s = 0.999,999,817$

FIGURE 2
Reliability Block Diagram of a Sequencer Channel and Reliability Calculations Summary

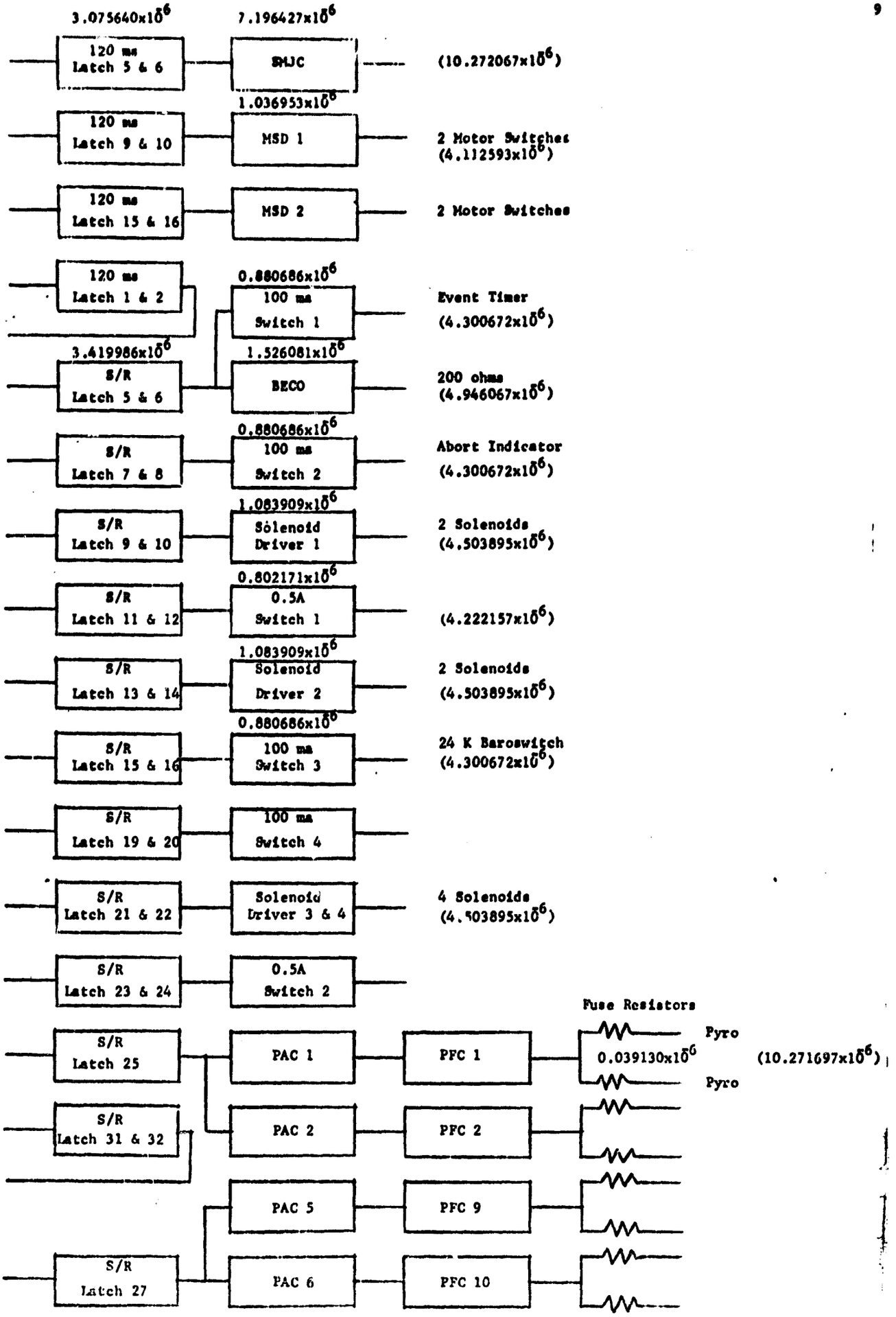


FIGURE 3

Output Circuit Details Showing
Unreliability of Each Block

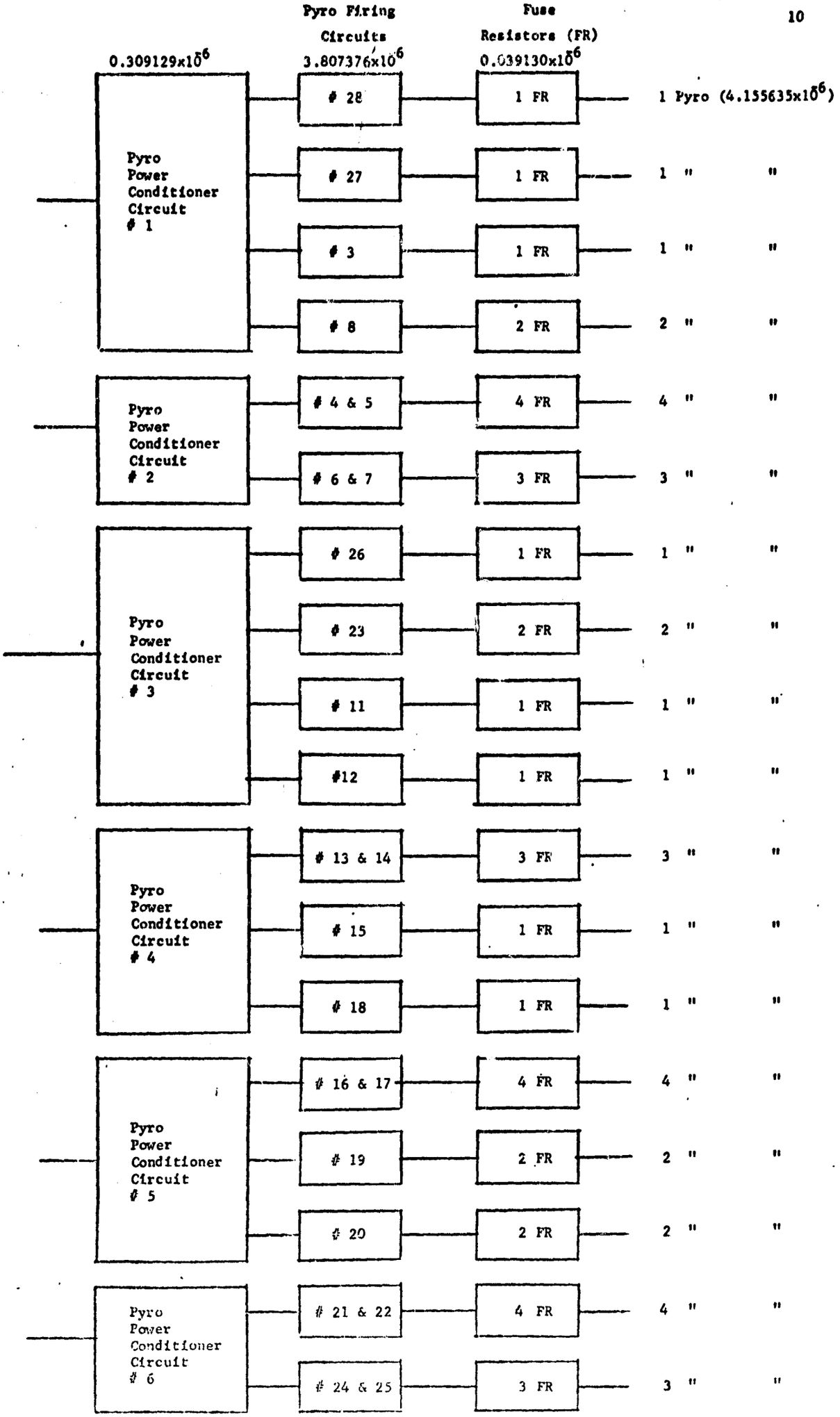


FIGURE 3. (Con't) - Output Circuit Details Showing Unreliability of Each Block

TABLE 2 - Event Logic Unreliability

SUBSYSTEM: Event Logic

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $\bar{f}_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\times 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET $\times 10^{-9}$
Input Filter (Positive Going)	5200-215	36 - Series Pair	1.81	65.160	24*	156	0	1563.840	10,164.960	0	11,728.800	
Input Filter (Zero Going)	5200-215, 220	22 - Series Pair	2.21	48.620	2.78×10^{-3}	156	6*	135.164×10^{-3}	7584.720	291.720	7876.575	
Sequence Gen.	5200-216, 219	2 - Series Pair	16.42	32.840	2.78×10^{-3}	3.3	388	91.295×10^{-3}	108.372	12,741.920	12,859.383	
Clear and Advance Amps	5200-217, 218 214 (2 of 2)	6 - Series Pair	2.05	12.300	2.78×10^{-3}	158.4	0	34.194×10^{-3}	1948.320	0	1948.354	
CTL Circuits	5200-216, 217 218,219	176 - Series Pair	0.55	96.800	2.78×10^{-3}	3.3	388	269.104×10^{-3}	319.440	37558.400	37,878.109	
Filter Capacitors	5200-216, 217, 218, 219	1 - Series Pair	0.72	0.720	1551	3.3	0	1116.720	2.376	0	1119.096	

TOTAL: $Q_1 = 73,401.317 \times 10^{-9}$

* These circuits get power from an external signal input. Twenty-four hours is assumed the maximum duration of these signals.

TABLE 3 - Event Logic Circuit Failure Rates

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
Event Logic						
Input Filter	Capacitor	1	K2R75100KS	KEMET	0.10	0.10
	Capacitor	1	Neptune	San Fern.	0.1	0.10
Positive Going Ckt. (36 Ckts)	Resistors	4	MF5C	Electra	0.1	0.40
	Diode	1	1N4148	G.E.	0.15	0.15
	Diode	1	IN4608	G.E.	0.15	0.15
	Zener Diode	1	1N963B	Motorola	0.17	0.17
	Inductor	1		Martin	0.1	0.1
	Transistor	1	2N2907A	FSC	0.20	0.20
	Transistor	1	2N2221A	Motorola	0.20	0.20
	Solder Joints	24			0.01	0.24
						1.81
Input Filter Zero Going Ckts (22 Ckts)	Capacitor	1	Neptune	San Fern.	0.10	0.10
	Capacitor	1	K2R75100KS	Kemet	0.10	0.10
	Resistors	4	MF5C	Electra	0.10	0.40
	Diode	1	1N4608	G.E.	0.15	0.15
	Diode	2	1N4148	G.E.	0.15	0.30
	Zenor Diode	1	1N967B	Motorola	0.17	0.17
	Zenor Diode	1	1N963B	Motorola	0.17	0.17
	Transistor	1	2N2221A	Motorola	0.20	0.20
	Transistor	1	2N2907A	FSC	0.20	0.20
	Inductor	1		Martin	0.10	0.10
	Solder Joints	32			0.01	0.32
						2.21
Power Filters	Capacitors (Tantalum)	6	Solid Tantalum	Sprague	0.10	0.60
	Solder Joints	12		MMC	0.01	0.12
						0.72
Sequence Generator	Capacitors	8	Neptune	San Fern	0.10	0.80
	Capacitor	1	K2R7J100KS	Kemet	0.10	0.10
	Resistors	27	MF5C	Electra	0.10	2.70
	Diodes	7	1N4148	G.E.	0.15	1.05
	Zener Diode	1	1N756A	T.I.	0.17	0.17
	Transistors	8	2N3947	Motorola	0.20	1.60
	Transistor	1	MM3737	Motorola	0.20	0.20
	Transistors	3	2N3251	Motorola	0.20	0.60
	Transistor	1	2N3765	Motorola	0.20	0.20
	Core Transistor Logic	6		MMC	1.1	6.60
	Solder Joints	240			0.01	2.40
						16.42

TABLE 3 - Event Logic Circuit Failure Rates (Con't)

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	G_{fr} x 10^{-9}	N x G_{fr} x 10^{-9}
ADVANCE and CLEAR Amplifiers (6 Ckts)	Resistors	6	MF5C	Electra	0.10	0.60
	Capacitor	1		USCC	0.10	0.20
	Diodes	2	IN4608	G. E.	0.15	0.30
	Transistor	1	2N3947	Motorola	0.20	0.20
	Transistor	1	2N3765	Motorola	0.20	0.20
	Transistor	1	MM3737	Motorola	0.20	0.20
	Solder Joints	35			0.01	0.35
						2.05
CTL Circuit	Capacitor	1		USCC	0.10	0.10
	Diode	1	IN4608	GE	0.01	0.01
	Transistor	1	2N2221A	Motorola	0.20	0.20
	Resistor	1	MF5C	Electra	0.10	0.10
	Inductor	1	846T250 -3E24	Ferrox Cube	0.10	0.10
	Permaloy Core	1	80529-1/20 -MA	Magnetics	0.01	0.01
	Solder Joints	13			0.01	0.13
						0.65

TABLE 4 - Timing Unreliability

SUBSYSTEM: Timing

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $f_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\times 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET $\times 10^{-9}$
8 MHz Clock	5200-222	1 - None*	2.42	2.42	1551	3.3	0	3753.420	7.986	0	3761.406	
TO-T9 Gen	5200-227 Page 2 & 4	2 - Series Pair	2.21	4.42	1551	3.3	0	6855.420	14.586	0	6870.006	
10 & 100 KHz Gen	5200-227 Page 3	2 - Series Pair	1.32	2.64	1551	3.3	0	4094.640	8.712	0	4103.352	
SC Fault Circuit	5200-227 Page 5	1 - See Note 1	0.85	0.85	1551	3.3	0	1318.350	2.805	0	1321.155	
Clear Clk Gen	5200-227 Page 1	1 - See Note 2	0.51	0.51	1551	3.3	0	791.10	1.683	0	792.693	
Fault Detection	5200-227 Page 6	1 - See Note 1	2.21	2.21	1551	3.3	0	3427.710	7.293	0	3435.003	
Caution Detection	5200-227 Page 7	1 - See Note 1	2.70	2.70	1551	3.3	0	4187.700	8.910	0	4196.610	
Timer Comparison	5200-227 Page 8	1 - See Note 1	3.83	3.83	1551	3.3	0	5940.330	12.639	0	5952.962	
Time Delay Logic	5200-227 Page 9	2 - Series Pair	1.80	3.60	1551	3.3	0	5583.600	11.880	0	5595.480	
Filter Capacitor Net Work	5200-227 Page 9	1 - See Note 1	0.84	0.84	1551	3.3	0	1302.840	2.772	0	1305.612	
									TOTAL: Q_2 = 37,334.279 x 10^{-9}			

*A failure will not produce an inadvertent output and will completely stop channel operation.

NOTE 1 - Failures must occur in both this circuit and another circuit in the system in order to produce an inadvertent output.

TABLE 5 - Timing Circuit Failure Rates

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	G_{fr} x 10^{-9}	N x G_{fr} x 10^{-9}
8 MHz Clock Ckt. (1 Ckt.)	8 MHz - Crystal	1	KTO-69-30	Monitor	0.10	0.10
	Transistor	3	2N3227	Motorola	0.20	0.60
	Resistors	9	MF5C	Electra	0.10	0.90
	Capacitor	1	150D	Sprague	0.10	0.10
	Capacitor	2	Neptune	San Fern.	0.10	0.20
	Integrated Ckt.	1	SW5430	T.I.	0.03	0.03
	Solder Joints	49			0.01	0.49
						2.42
T0-T9 Gen.	Integrated Circuits	7	SN5473	T.I.	0.03	0.21
	Integrated Circuits	1	SN5430	T.I.	0.03	0.03
	Integrated Circuits	1	SN5400	T.I.	0.03	0.03
(2 Ckts)	Integrated Circuits	1	SN5402	T.I.	0.03	0.03
5200-227 Page 2	Integrated Circuits	3	SN5440	T.I.	0.03	0.09
5200-227 Page 4	Solder Joints	182			0.01	1.82
						2.21
10 & 100 KHz Gen.	Integrated Circuits	2	SN54L00	T.I.	0.03	0.06
	Integrated Circuits	1	SN54L20	T.I.	0.03	0.03
(2 Ckts)	Integrated Circuits	1	SN5402	T.I.	0.03	0.03
	Integrated Circuits	1	SN5401	T.I.	0.03	0.03
	Integrated Circuits	2	SN54121	T.I.	0.03	0.06
5200-227	Resistor	1	MF5C	Electra	0.10	0.10
Page 3	Solder Joints	101			0.01	1.01
						1.32
SC Fault Circuit	Integrated Circuits	2	SN5486	T.I.	0.03	0.06
	Integrated Circuits	2	SN5402	T.I.	0.03	0.06
(1 Ckt.)	Integrated Circuits	1	SN5430	T.I.	0.03	0.03
5200-227	Solder Joints	70		T.I.	0.01	0.70
						0.85
Clear Clock Gen.	Integrated Circuits	1	SN5440	T.I.	0.03	.03
	Integrated Circuits	1	SW5474	T.I.	0.03	.03
	Integrated Circuits	1	SN5400	T.I.	0.03	.03
5200-227	Solder Joints	42		MMC	0.01	0.42
						0.51
Filter Capacitor Network	Capacitors	7			0.1	0.7
	Solder Joints	14			0.01	.14
						0.84

TABLE 5 - Timing Circuit Failure Rates (Con't)

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
Fault Detection Circuits 5200-227 Page 6	Integrated Circuit	2	SN5430	T.I.	0.03	0.06
	Integrated Circuit	1	SN5474	T.I.	0.03	0.03
	Integrated Circuit	1	SN54L74	T.I.	0.03	0.03
	Integrated Circuit	2	SN5402	T.I.	0.03	0.06
	Integrated Circuit	1	SN5400	T.I.	0.03	0.03
	Integrated Circuit	1	MD2218A	Motorola	0.40	0.40
	Resistors	2	MF5C	Electra	0.1	0.20
	Solder Joints	140			0.01	1.40
						2.21
Caution Detection 5200-227 Page 7	Integrated Circuit	3	SN5474	T.I.	0.03	0.09
	Integrated Circuit	4	SN54L73	T.I.	0.03	0.12
	Integrated Circuit	3	SN5400	T.I.	0.03	0.09
	Resistors	3	MF5C	Electra	0.10	0.30
	Diode	1	1N4608	G.E.	0.10	0.10
	Integrated Transistor Ckt.	1	MD2218A	Motorola	0.40	0.40
	Solder Joints	160			0.01	1.60
						2.70
Timer Comparison Logic 5200-227 Page 8	Capacitor	3	Neptune	San Fern.	0.10	0.30
	Resistor	8	MF5C	Electra	0.10	0.80
	Integrated Circuit	1	MD2218A	Motorola	0.40	0.40
	Integrated Circuit	3	SN54L00	T.I.	0.03	0.09
	Integrated Circuit	3	SW5474	T.I.	0.03	0.09
	Integrated Circuit	2	SW54L74	T.I.	0.03	0.06
	Integrated Circuit	2	SW5402	T.I.	0.03	0.06
	Integrated Circuit	1	SW5410	T.I.	0.03	0.03
	Solder Joints	200			0.01	2.00
						3.83
Time Delay Logic 5200-227 Page 9	Resistor	4	MF5C	Electra	0.10	0.40
	Integrated Circuits	1	MD2218A	Motorola	0.40	0.40
	Integrated Circuits	1	SW5410	T.I.	0.03	0.03
	Integrated Circuits	1	SW5400	T.I.	0.03	0.03
	Integrated Circuits	1	SW54L00	T.I.	0.03	0.03
	Integrated Circuits	1	SW54L74	T.I.	0.03	0.03
	Integrated Circuits	1	SW5474	T.I.	0.03	0.03
	Solder Joints	85			0.01	0.85
						1.80

TABLE 6 - Memory Unreliability

SUBSYSTEM: Memory

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $f_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\times 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET $\times 10^{-9}$
Sense Amplifiers	5400-44	12 - Functional Parallel Pair (FPP)	0.99	0.99	2.78×10^{-3}	158.4	0	2.7522×10^{-3}	156.816	0	156.819	$66Q_p^2$ .0016231
Memory Switch Circuits	5400-46 (6 ckts) 5400-42 (6 ckts) 5400-43 (4 ckts) 5400-46 (6 ckts) 5400-45 (2 ckts)	24 - Functional Series - Parallel Pairs (FSPP)	1.80	1.80	2.78×10^{-3}	158.4	0	5.004×10^{-3}	285.120	0	285.125	$276Q_p^2$ .02243777
Memory Inhibit Drivers	5400-41	12 - FPP	4.30	4.30	2.78×10^{-3}	158.4	0	11.954×10^{-3}	679.400	0	679.412	$66Q_p^2$ .0304656
Memory Drivers	5400-42 (4 ckts) 5400-43 (4 ckts) 5400-44 (1 ckt) 5400-45 (8 ckts) 5400-46 (6 ckts) 5400-41 (1 ckt)	24 - FSPP	4.30	4.30	2.78×10^{-3}	158.4	0	11.954×10^{-3}	679.400	0	679.412	$276Q_p^2$ 0.1274017
Decoding Logic	5400-47 5400-48	2 - FSPR	3.08	3.08	2.78×10^{-3}	158.4	0	8.5624×10^{-3}	487.872	0	487.881	Q_p^2 0.000238
T&C Circuit	5400-48	3 - TRMV	2.90	2.90	2.78×10^{-3}	158.4	0	8.062×10^{-3}	459.360	0	459.368	$3Q_p^2$ 0.000533
T&C Majority Voter	5400-48	1 - Note 1	1.96	1.96	2.78×10^{-3}	158.4	0	5.449×10^{-3}	310.464	0	310.469	310.469
Clamp Voltage Generator	5400-49	1 - None; Note 1	5.57	5.57	2.78×10^{-3}	158.4	0	15.485×10^{-3}	882.288	0	882.288	882.288
Memory Stack		2 - FPP	12.47	12.47	2.78×10^{-3}	158.4	0	34.666×10^{-3}	1975.248	0	1975.283	Q_p^2 0.0039017

TOTAL: $Q_3 = 1192.943\times10^{-9}$

TABLE 7 - MEMORY Circuits Failure Rates

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
Sense Amplifiers (12 Ckts)	Resistor	6	MF5C	Electra	0.1	0.6
	Op. Amp.	1	MC1711	Motorola	0.03	0.03
	Solder Joints	36			0.01	0.36
						.99
Memory Switch Ckts. (24 Ckts)	Solder Joints	30			0.01	0.30
	Resistor	4	MF5C	Electra	0.1	0.4
	Diode	2	IN4608	GE	0.15	0.3
	Transistor	2	2N3765	Motorola	0.2	0.4
	Transistor	2	MM3737	Motorola	0.2	0.4
						1.80
Memory Inhibit Driver Ckts (12 Ckts)	Resistors	11	MF5C	Electra	0.1	1.1
	Capacitors	4	Neptune	San Fern.	0.1	0.4
	Diodes	7	IN4608	GE	0.15	1.05
	Transistors	2	2N3947	Motorola	0.2	0.4
	Transistors	2	2N3251	Motorola	0.2	0.4
	Transistors	2	MM3737	Motorola	0.2	0.4
	Solder Joints	60			0.01	0.60
						4.35
Memory Driver Ckts. (24 Ckts)	Resistors	11	MF5C	Electra	0.1	1.1
	Capacitors	4	Neptune	San Fern.	0.1	0.4
	Diodes	7	IN4608	GE	0.15	1.05
	Transistors	2	2N3947	Motorola	0.2	0.4
	Transistors	2	2N3251	Motorola	0.2	0.4
	Transistors	2	MM3737	Motorola	0.2	0.4
	Solder Joints	60			0.01	0.6
						4.35
Decoding Logic Ckt. (2 Ckts)	Triple 3-Input Positive NAND Gates	8	SN5410	T.I.	0.03	0.24
	Quadruple 2-Input Positive Nor-Gate		SN5402	T.I.	0.03	0.33
	Solder Joints	250			0.01	2.50
						3.07
T&C Ckts. (3 Ckts)	Resistors	8	MF5C	Electra	0.1	0.8
	Capacitors	8	Neptune	San Fern.	0.1	0.8
	Integrated Ckt. (One Shot)	8	SN54121	T.I.	0.03	0.24
	Integrated Circuit Positive Nor Gate	1	SN5402	T. I.	0.03	0.03
	Integrated Circuit	1	SN5400	T.I.	0.03	0.03
	Solder Joints	100			0.01	1.00
						2.90

TABLE 7 - MEMORY Circuits Failure Rates (Con't)

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
T&C Majority Voter Ckt. (1 Ckt)	Quadruple 2-Input NAND-Gate	4	SN5400	T.I.	0.03	0.12
	Quadruple 2-Input NOR-Gate	4	SN5402	T.I.	0.03	0.12
	Quadruple 2-Input Exclusive-OR Gates	4	SN5486	T.I.	0.03	0.12
	Dual 4-Input Positive NAND Buffer	2	SN5440	T.I.	0.03	0.12
	Solder Joints	150			0.01	1.50
						1.98
Clamp Voltage Generator	Resistors	20	MF5C	Electra	0.10	2.00
	Capacitors	4	150D	Sprague	0.10	0.40
	Diodes	4	IN4148	G.E.	0.15	0.60
	Diode (Zener)	2	IN764	T.I.	0.17	0.34
	Transistor	2	2N2221A	Motorola	0.20	0.40
	Transistor	2	2N4031	Fairchild	0.20	0.40
	Transistor	2	2N2907	Fairchild	0.20	0.40
	Operational Amplifier	1	MC1711	Motorola	0.03	0.03
	Solder Joints	100			0.01	1.00
						5.57
One-Half Memory Stack	Diodes	64	IN4608	G.E.	0.15	9.60
	Solder Joints	287	IN4608	G.E.	0.01	2.87
	Cores	6,144			Negl.	
						12.47

TABLE 8 - Memory Register Unreliability

SUBSYSTEM: Memory Register

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $f_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE x 10^{-9}	DORMANT x 10^{-9}	NON OP. x 10^{-9}	TOTAL x 10^{-9}	REDUNDANT SET x 10^{-9}
mory Register	5200-229 Pages 2 - 5	2 - Parallel Pair	3.60	3.60	2.78×10^{-3}	158.4	0	10.008×10^{-3}	570.240	0	570.250	Q_p^2 0.000325
dundant Gates	5200-229 Pages 6 & 7	1 - None; See Note 1	3.04	3.04	2.78×10^{-3}	158.4	0	8.451×10^{-3}	481.536	0	481.544	481.544
Fault Ckt.	5200-229 Page 1	1 - None*	1.21	N/A	2.78×10^{-3}	158.4	0	N/A	N/A	0	0	0
rity Check rcuit	5200-229 Page 8	1 - See Note 1	0.68	0.68	2.78×10^{-3}	158.4	0	1.890×10^{-3}	107.712	0	107.714	107.714
lter Capacitor twork	5200-229	1 - See Note 1	0.84	0.84	2.78×10^{-3}	158.4	0	2.335×10^{-3}	133.056	0	133.058	133.058
									TOTAL: Q_s = 722.316 x 10^{-9}			

*A failure in this circuit does not affect total system operation. It indicates that a single failure has occured in the memory system.

TABLE 9 - MEMORY REGISTER Circuit Failure Rates

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	G_{fr} x 10^{-9}	N x G_{fr} x 10^{-9}
Memory Register (2 Ckts.)	Integrated Circuit	6	SN5474	T.I.	0.03	0.18
	Integrated Circuit	12	SN5400	T.I.	0.03	0.36
	Integrated Circuit	2	SN5440	T.I.	0.03	0.06
	Solder Joints	300			0.01	3.00
						3.60
Redundant Gates (1 Ckt.)	Integrated Circuit	12	SN5450	T.I.	0.03	0.36
	Integrated Circuit	3	SN5486	T.I.	0.03	0.09
	Integrated Circuit	2	SN5400	T.I.	0.03	0.06
	Integrated Circuit	1	SN5420	T.I.	0.03	0.03
	Integrated Circuit	3	SN5402	T.I.	0.03	0.09
	Integrated Circuit	1	SN5430	T.I.	0.03	0.03
	Integrated Circuit	1	SN5440	T.I.	0.03	0.03
	Solder Joints	235			0.01	2.35
						3.04
MR Fault Ckt. (1 Ckt.) 11-Bit Comparator	Integrated Circuit	3	SN5486	T.I.	0.03	0.09
	Integrated Circuit	2	SN5402	T.I.	0.03	0.06
	Integrated Circuit	2	SN5410	T.I.	0.03	0.06
	Solder Joints	100			0.01	1.00
						1.21
Parity Check Ckt. A Even (1 Ckt)	Integrated Circuit	3	SN5486	T.I.	0.03	0.09
	Integrated Circuit	3	SN5402	T.I.	0.03	0.09
	Solder Joints	50			0.01	0.5
						0.68
Filter Capacitors	Capacitor	7		Sprague	0.10	0.70
	Solder Joints	14		MMC	0.01	0.14
						0.84

TABLE 10 - Address Register Unreliability

SUBSYSTEM: Address Register

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RT. $f_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE x x 10^{-9}	DORMANT x 10^{-9}	NON OP. x 10^{-9}	TOTAL x 10^{-9}	REDUNDANT SET
Address Register	5200-232 (Pages 1 - 5) 5200-231 (Pages 1 - 3)	3 - TRMV	6.22	6.22	2.78×10^{-3}	158.4	0	17.291×10^{-3}	985.248	0	985.265	$3Q_p^2$ 0.00291
AR Majority Voter	5200-232 (Pages 6 - 8) 5200-231 (Pages 4 6)	2 - Series Pair	4.09	8.18	2.78×10^{-3}	158.4	0	22.740×10^{-3}	1295.712	0	1295.735	1295.735
Storage Address Register	5200-222	3 - TRMV (30 CTL Ckts)	5.50 (Ten CTLs)	5.50	2.78×10^{-6}	3.3	388	Negl.	18.150	2134.000	2152.150	$3Q_p^2$ 0.01389
Filter Networks		30 Networks in groups of 10 - TRMV	2.5 (For a group of 10)	2.5	2.78×10^{-3}	158.4	0	6.95×10^{-3}	396.000	0	396.007	$3Q_p^2$ 0.00047
CTL Advance Amps	5200-222	3 - TRMV	3.05	3.05	2.78×10^{-3}	158.4	0	8.479×10^{-3}	483.120	0	483.128	$3Q_p^2$ 0.00070
Set Amps	5200-232	3 - TRMV	0.40	0.40	2.78×10^{-3}	158.4	0	1.112×10^{-3}	63.360	0	63.361	Negl.
									TOTAL: Q_S =	1295.753 x 10^{-9}		

TABLE 11 - Address Register Circuit Failure Rates

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
Address Register (3 Ckts.)	Integrated Ckts.	5	SN5474	T.I.	0.03	0.15
	Integrated Ckts.	11	SN5400	T.I.	0.03	0.33
	Integrated Ckts.	5	SN5482	T.I.	0.03	0.15
	Integrated Ckts.	4	SN5410	T.I.	0.03	0.12
	Integrated Ckts.	3	SN5440	T.I.	0.03	0.09
	Solder Joints	377			0.01	3.77
						4.61
AR Majority Voter (2 Ckts)	Integrated Ckts.	10	SN5450	T.T.	0.03	0.30
	Integrated Ckts.	7	SN5486	T.I.	0.03	0.21
	Integrated Ckts.	5	SN5402	T.I.	0.03	0.15
	Integrated Ckts.	2	SN5400	T.I.	0.03	0.06
	Integrated Ckts.	1	SN5410	T.I.	0.03	0.03
	Solder Joints	334			0.01	3.34
						4.09
Storage Address Register (3 Ckts)	Capacitor	11	Neptune	San Fern.	0.10	1.1
	Resistor	11	MF5C	Electra	0.10	1.1
	CTL Element	11		MMC	1.10	12.10
	Transistor	11	2N2221A	Motorola	0.20	2.20
	Solder Joints	100			0.01	1.00
						17.50
Filter Net Works (3 Ckts.)	Capacitor	10	Neptune	San Fern.	0.10	1.0
	Resistors	10	MF5C	Electra	0.10	1.0
	Solder Joints	50			0.01	0.5
						2.5
CTL Adv. Amp.	Transistor	1	2N3947	Motorola	0.20	0.20
	Transistor	1	2N3765	Motorola	0.20	0.20
	Transistor	1	MM3737	Motorola	0.20	0.20
	Diode	2	IN4608	G.E.	0.15	0.30
	Resistor	6	MF5C	Electra	0.10	0.60
	Capacitor	1	Neptune	San Fern.	0.10	0.10
	CTL	1		MMC	1.10	1.10
	Solder Joints	35		MMC	0.01	0.35
						3.05
Set Amp	Transistor	1	MD2218A	Motorola	0.20	0.20
	Resistor	1	MF5C	Electra	0.10	0.10
	Solder Joints	10		MMC	0.01	0.10
						0.40

TABLE 12 - Control Logic Unreliability

SUBSYSTEM: Dual Redundant Control Logic

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $f_r \times 10^9$	$Nf_r \times 10^9$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\times 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET $\times 10^{-9}$
Memory Control	5200-233 Page 2	2 - Series Pair	1.80	3.60	2.78×10^{-3}	158.4	0	10.008×10^{-3}	570.240	0	570.250	
Branch Control	5200-233 Page 4	1 - Series Pair	3.07	3.07	2.78×10^{-3}	158.4	0	8.534×10^{-3}	486.288	0	486.297	
Power Hold	5200-233 Page 5	1 - Series Pair	1.33	1.33	2.78×10^{-3}	158.4	0	3.6974×10^{-3}	210.672	0.	210.676	
Memory Control B	5200-233 Page 6	1 - Series Pair	1.83	1.83	2.78×10^{-3}	158.4	0	5.0874×10^{-3}	289.872	0	289.877	
MCA Fault Detection	5200-233 Page 1	1 - None; Note 1	1.21	1.21	2.78×10^{-3}	158.4	0	3.3638×10^{-3}	191.664	0	191.667	
P.S. Control Logic	5200-233 Page 8	1 - None; Note 1	2.07	2.07	1551	3.3	0	3210.570	6.8310	0	3217.401	
Read Logic	5200-234 Page 1, 4	2 - Series Pair	(3 ICs)0.09 1.60	0.18 3.20	1551 2.78×10^{-3}	3.3 158.4	0 0	279.180 8.8960×10^{-3}	0.594 506.880	0 0	279.774 506.889	
Read Control	5200-234 Page 2, 5	2 - Series Pair	(2 ICs)0.06 2.37	0.12 4.74	1551 2.78×10^{-3}	3.3 158.4	0 0	186.120 13.1772×10^{-3}	0.396 750.816	0 0	186.516 750.829	
Set Control Logic	5200-234 Page 3,6	2 - Series Pair	2.29	4.58	2.78×10^{-3}	158.4	0	12.7324×10^{-3}	725.472	0	725.485	
Memory Control Fault	5200-233 Page 7	1 - None; Note 1	1.36	1.36	2.78×10^{-3}	158.4	0	3.7808×10^{-3}	215.424	0	215.428	
Power Logic	5200-229 5200-231 Page 9	2 - Series Pair	(3 Ics)0.09 1.89	0.18 3.78	1551 2.78×10^{-3}	3.3 158.4	0 0	279.180 10.5084×10^{-3}	0.594 593.752	0 0	279.774 498.763	
Memory Word Reg.	5290 - 228 5200 - 230 Page 4	2 - Series Pair	0.82	1.64	2.78×10^{-3}	158.4	0	4.5592×10^{-3}	259.776	0	259.781	
Set Cmd. Bits	5200-228 5200-230 Page 2	2 - Series Pair	3.42	6.84	2.78×10^{-3}	158.4	0	19.0152×10^{-3}	1083.456	0	1083.475	
Set Event Gates	5200-228 5200-230 Page 3	2 - Series Pair	6.78	13.56	2.78×10^{-3}	158.4	0	37.6968×10^{-3}	2147.904	0	2147.942	

TABLE 12 - Control Logic Unreliability (Con't)

SUBSYSTEM: Dual Redundant Control Logic

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $f_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\times 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET $\times 10^{-9}$
Branch Set Gates	5200-228 5200-230 Page 4	2 - Series Pair	6.25	12.50	2.78×10^{-3}	158.4	0	34.7500×10^{-3}	1980.000	0	1980.035	
Set Inhibit Gates	5200-228 5200-230 Page 4	2 - Series Pair	1.20	2.40	2.78×10^{-3}	158.4	0	6.6720×10^{-3}	380.160	0	380.167	
Set Timing Gates	5200-228 5200-230 Page 3	2 Series Pair	2.06	4.12	2.78×10^{-3}	158.4	0	11.4536×10^{-3}	652.608	0	562.619	
Timing Bit Logic	5200-228 5200-230 Page 1	2 - Series Pair	0.85	1.70	2.78×10^{-3}	158.4	0	4.7260×10^{-3}	269.280	0	269.285	
Decoder Driver	5200-213 5200-214	2 - Series Pair	4.29	8.58	2.78×10^{-6}	3.3	388	Negl.	28.314	3329.040	3357.354	
Command Register Stage	5200-213 5200-214	12 - Series Pair	0.74	8.88	2.78×10^{-6}	3.3	388	Negl.	29.304	3445.440	3474.744	
Decoding Submatrix	5200-213 5200-214	2 - Series Pair	0.52	1.04	2.78×10^{-6}	3.3	388	Negl.	3.432	403.520	406.952	
Reset Driver	5200-214	1 - None Note 1	3.00	3.00	1551	3.3	0	4653.00	9.90	0	4662.90	
Power Up Reset Ckt.	5200-213 5200-214	2 - Series Pair	2.38	4.76	1551	3.3	0	7382.76	15.708	0	7398.468	
Filter Capacitors	5200-228 5200-229 5200-230 5200-231 5200-233 5200-234	1 Series Pair	4.20	4.20	1551	3.3	0	6514.200	13.860	0	6528.060	
									TOTAL: Q_6 =	45,774.308	$\times 10^{-9}$	

TABLE 13 - Control Logic Circuit Failure Rates

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
Mem. Control A. (1 Ckt.)	Integrated Circuit	6	SN5400	T.I.	0.03	0.18
	Integrated Circuit	3	SN5402	T.I.	0.03	0.09
	Integrated Circuit	1	SN5410	T.I.	0.03	0.03
	Solder Joints	140			0.01	1.40
	Capacitor	1	Neptune	San Fern.	0.1	0.10
						1.80
Branch Control Circuit 1 Ckt. (But Ckt. is dual Red)	Integrated Circuit	6	SN5473	T.I.	0.03	0.18
	Integrated Circuit	2	SN5474	T.I.	0.03	0.06
	Integrated Circuit	3	SN5440	T.I.	0.03	0.09
	Integrated Circuit	2	SN5400	T.I.	0.03	0.06
	Integrated Circuit	4	SN5402	T.I.	0.03	0.12
	Integrated Circuit	2	SN5420	T.I.	0.03	0.06
	Solder Joints	250			0.01	2.50
						3.07
PW Hold Circuit (1 Ckt)	Integrated Circuit	2	SN5473	T.I.	0.03	0.06
	Integrated Circuit	4	SN5472	T.I.	0.03	0.12
	Integrated Circuit	2	SN5410	T.I.	0.03	0.06
	Integrated Circuit	1	SN5440	T.I.	0.03	0.03
	Solder Joints	106			0.01	1.06
						1.33
Memory Control (1 Ckt.)	Integrated Circuit	3	SN5400	T.I.	0.03	0.09
	Integrated Circuit	2	SN5402	T.I.	0.03	0.06
	Integrated Circuit	4	SN5410	T.I.	0.03	0.12
	Integrated Circuit	2	SN5420	T.I.	0.03	0.06
	Solder Joints	150			0.01	1.50
						1.83
MCA Fault Det. Ckt. (1 Ckt.) 5200-233 Page 1	Integrated Circuit	4	SN5486	T.I.	0.03	0.12
	Integrated Circuit	2	SN5402	T.I.	0.03	0.06
	Integrated Circuit	1	SN5430	T.I.	0.03	0.03
	Solder Joints	10			0.01	1.00
						1.21
P.S. Control Logic Ckt. (1 Ckt) 5200-233	Resistors	5	MF5C	Electra	0.10	0.50
	Capacitors	4	Neptune	San Fern.	0.10	0.40
	Integrated Circuit	1	SN54121	T.I.	0.03	0.03
	Integrated Circuit	2	SN5400	T.I.	0.03	0.06
	Integrated Circuit	1	SN5401	T.I.	0.03	0.03
	Diodes	2	1N4148	G.E.	0.15	0.30
	Solder Joints	75			0.01	0.75
						2.07

TABLE 13 - Control Logic Circuit Failure Rates (Con't)

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	G_{fr} x 10^{-9}	N x G_{fr} x 10^{-9}
Read Logic Circuit (1 Ckt.)	Integrated Circuit	1	SN54L74	T.I.	0.03	0.03
	Integrated Circuit	1	SN5474	T.I.	0.03	0.03
	Integrated Circuit	2	SN54L00	T.I.	0.03	0.06
	Integrated Circuit	1	SN5402	T.I.	0.03	0.03
	Integrated Circuit	2	SN5400	T.I.	0.03	0.06
	Integrated Circuit	1	SN5402	T.I.	0.03	0.03
	Resistor	2	MF5C	Electra	0.1	0.20
	Capacitor	1	Neptune	San Fern.	0.15	0.15
	Solder Joints	110			0.01	1.10
						1.69
Read Control Logic (1 Ckt)	Integrated Circuit	7	SN5474	T.I.	0.03	0.21
	Integrated Circuit	1	SN54L74	T.I.	0.03	0.03
	Integrated Circuit	1	SN54L00	T.I.	0.03	0.03
	Integrated Circuit	3	SN5400	T.I.	0.03	0.09
	Integrated Circuit	2	SN5402	T.I.	0.03	0.06
	Integrated Circuit	2	SN5410	T.I.	0.03	0.06
	Resistor	3	MF5C	Electra	0.10	0.30
	Capacitor	3	Neptune	San Fern.	0.10	0.30
	Solder Joints	135			0.01	1.35
						2.43
Set Control Logic Circuit	Integrated Circuit	2	SN5400	T.I.	0.03	0.06
	Integrated Circuit	1	SN5401	T.I.	0.03	0.03
	Integrated Circuit	1	SN5402	T.I.	0.03	0.03
	Integrated Circuit	1	SN5410	T.I.	0.03	0.03
	Integrated Circuit	3	SN5440	T.I.	0.03	0.09
	Resistors	2	MF5C	Electra	0.1	0.20
	Integrated Circuit	2	MD2218A	Motorola	0.4	0.8
	Solder Joints	125			0.01	1.25
						2.49
Memory Control Fault (1 Ckt.)		4	SN5486	T.I.	0.03	0.12
		3	SN5402	T.I.	0.03	0.09
		1	SN5430	T.I.	0.03	0.03
	Solder Joints	112			0.01	1.12
						1.36
Power Logic	Resistor	3	MF5C	Electra	0.10	0.30
	Capacitor	1	Neptune	San Fran.	0.10	0.10
	Integrated Circuit	1	SN54L30	T.I.	0.03	0.03
	Integrated Circuit	1	SN54L74	T.I.	0.03	0.03
	Integrated Circuit	3	SN5474	T.I.	0.03	0.09
	Integrated Circuit	2	SN5400	T.I.	0.03	0.06
	Integrated Circuit	1	SN54L00	T.I.	0.03	0.03
	Integrated Circuit	1	SN5440	T.I.	0.03	0.03
	Solder Joints	134			0.01	1.34
						2.01
Memory Word Reg. (2 Ckts)	Integrated Circuit	6	SN5474	T.I.	0.03	0.18
	Solder Joints	64			0.01	.64
						0.82

TABLE 13 - Control Logic Circuit Failure Rates (Con't)

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
Set Cmd. Bits (1 Ckt.)	Integrated Circuit	3	SN5402	T.I.	0.03	0.09
	Transistors	6	MD2218A	Motorola	0.40	2.40
	Solder Joints	93			0.01	0.93
						3.42
Set Event Gates (2 Ckts)	Integrated Circuits	7	SN5402	T.I.	0.03	0.21
	Transistors	13	MD2218A	Motorola	0.40	5.20
	Solder Joints	137			0.01	1.37
						6.78
Branch Set Gates (2 Ckts)	Integrated Circuit	5	SN5402	T.I.	0.03	0.15
	Transistors	10	MD2218A	Motorola	0.40	4.00
	Solder Joints	210			0.01	2.10
						6.25
Set Inhibit Gates (2 Ckts)	Integrated Circuit	2	SN5402	T.I.	0.03	0.06
	Transistors	2	MD2218A	Motorola	0.40	0.80
	Solder Joints	34			0.01	0.34
						1.20
Set Timing Gates (2 Ckts)	Integrated Circuits	2	SN5402	T.I.	0.03	0.06
	Transistors	4	MD2218A	Motorola	0.40	1.60
	Solder Joints	40			0.01	0.40
						2.06
Timing Bit Logic (2 Ckts).	Integrated Circuit	1	SN5420	T.I.	0.03	0.03
	Integrated Circuit	1	SN5400	T.I.	0.03	0.03
	Integrated Circuit	1	SN5440	T.I.	0.03	0.03
	Integrated Circuit	2	SN5430	T.I.	0.03	0.06
	Solder Joints	70			0.01	0.70
						.85

TABLE 13 - Control Logic Circuit Failure Rates (Con't)

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	G_{fr} x 10^{-9}	N x G_{fr} x 10^{-9}
Decoder Driver (2 Ckts)	Transistor	1	2N3947	Motorola	0.20	0.20
	Transistor	1	2N3765	Motorola	0.20	0.20
	Transistor	3	MM3737	Motorola	0.20	0.60
	Diodes	5	1N4608	G.E.	0.15	0.75
	Diode (Zener)	2	1N746A	T.I.	0.17	0.34
	Resistors	13	MF5C	Electra	0.10	1.30
	Capacitors	3	Neptune	San Fern.	0.10	0.30
	Permalloy Cores	1	80529-1/2D MA	Magnetics	0.01	0.01
	Solder Joints	59			0.01	0.59
						4.29
Command Register Stage	Diodes	2	1N4608	G.E.	0.15	0.30
	Resistor	2	MF5C	Electra	0.10	0.20
	Permalloy Cores	2	80529-12D MA	Magnetics	0.01	0.02
	Solder Joints	22			0.01	0.22
						0.74
Decoding Submatrix	Primary Cores	16	80529-1/2D MA	Magnetics	0.01	0.16
	Solder Joints	36			0.01	0.36
						0.52
Reset Driver	Transistors	2	2N3947	Motorola	0.20	0.40
	Transistor	1	2N3251	Motorola	0.20	0.20
	Transistor	1	MM3737	Motorola	0.20	0.20
	Capacitors	4	Neptune	San Fern.	0.10	0.40
	Diode (Zener)	1	1N961B	T.I.	0.17	0.17
	Resistors	13	MF5C	Electra	0.01	0.13
	Solder Joints	48			0.01	0.48
	Diodes	3	1N4608	G.E.	0.15	0.45
	Diodes	2	1N4148	G.E.	0.15	0.30
	Diode (Zener)	1	1N756A	T.I.	0.17	0.17
	Capacitor	1	K-Series	Kemet	0.10	0.10
						3.00
Power Up Reset Circuit (2 Ckts)	Permalloy Core	1	80524-1/20	Magnetics	0.01	0.01
	Transistors	1	2N3947	Motorola	0.20	0.20
	Transistors	1	2N3251	Motorola	0.20	0.20
	Transistor	1.	2N3737	Motorola	0.20	0.20
	Diode (Zener)	1	1N746A	T.I.	0.17	0.17
	Capacitors	1	DC---K	Nytronics	0.10	0.10
	Resistors	8	MF5C	IRC	0.10	0.80
	Solder Joints	53			0.01	0.53
	Diode (Zener)	1	1N756A	T.I.	0.17	0.17
						2.38
Filter Networks	Capacitor	35	Tantalum	Sprague	0.10	3.50
	Solder Joints	70			0.01	0.70
						4.20

TABLE 14 - Power Supply Unreliability

SUBSYSTEM: Power Supply

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAIL. RATE	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\times 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET
Power Supply	5300 - 42	1 - None*	38.18	38.18	1551	3.3	0	59,217.180	125.994	0	59,343.174	
									TOTAL: Q_s = 59,343.174 x 10^{-9}			

* Failure Detection circuitry is included and a failure in both the failure detection circuitry and the power supply circuitry is required to produce a system failure in the form of an inadvertent output.

TABLE 15 - Power Supply Circuit Failure Rates

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFC.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
Power Supply						
	Diodes	5	UTX 4110	Unitrade	0.15	0.75
	Diodes	9	1N4148	Fairchild	0.15	1.35
	Zeners Diode	1	IN752A	Motorola	0.17	0.17
	Transistors-FET	1	2N3459	Union Carb	0.20	0.20
	Transistors	1	2N2422	Fairchild	0.20	0.20
	Transistors	6	2N2907A	Motorola	0.20	1.20
	Transistors	3	2N3251	Motorola	0.20	0.60
	Transistors	1	2N2325A	Fairchild	0.20	0.20
	Transistors (SCR)	1	2N3655	G.E.	0.20	0.20
	Transistors	4	2N3507	Motorola	0.20	0.80
	Transistors	5	MM3737	Motorola	0.20	1.00
	Transistors	5	2N3947	Motorola	0.20	1.00
	Inductors	2			0.1	0.20
	Operational Amplifier	10	LM101	Fairchild	0.03	0.30
	Transistor	1	2N684	Motorola	0.20	0.20
	Diodes Zener	3	1N968B	Motorola	0.17	0.51
	Diodes Zener	5	LM103	National	0.17	0.85
	Integrated Circuit	1	SN5430	T.I.	0.03	0.03
	Integrated Ckt.	1	SN5400	T.I.	0.03	0.03
	Diode	1	IN748A		0.15	0.15
	Resistor	2	AS-1/2	IRC	0.10	0.20
	Resistor	1	AS-1	IRC	0.10	0.10
	Resistor	127	MF5C	Electra	0.10	12.70
	Diodes	14	UTX 215	Unitrode	0.15	2.10
	Transistor	1	2N3765	Motorola	0.2	0.20
	Transistor	2	2N4398	Motorola	0.2	0.40
	Transistor	2	2N5002	Fairchild	0.2	0.40
	Transistor	2	2N5153	Fairchild	0.2	0.40
	Transformer	4	104 To Go -3 EA	Ferrox Cube	.01	0.04
	Transistor	1	2N2422B	G.E.	0.2	0.20
	Filter	2	2120-013	USCC	0.10	0.20
	Insulated Capacitor	18	1250-003	Erie	0.10	1.8
	Capacitors	61	K-series	Kemet	0.10	6.1
	Capacitors	34	Neptune	San Fern.	0.10	3.4
	Capacitors	9	150 D	Sprague	0.10	0.9
	Capacitor	1	C20-Series	USCC	0.10	0.1
						38.18

TABLE 16 - Output Feedback Unreliability

SUBSYSTEM: Output Feedback Circuits

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $f_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\approx 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET $\times 10^{-9}$
ELB Clear Drivers	5200-210	4 - Series Pair	3.70	14.80	2.78×10^{-3}	3.3	388	41.144×10^{-3}	48.840	5742.400	4791.281	
Set-Reset Output Latch	5200-205	2 - Series Pair	4.37	8.74	2.78×10^{-3}	3.3	388	24.297×10^{-3}	28.842	3391.120	3419.986	
0.120 Second Latch	5200-208	2 - Series Pair	3.93	7.86	2.78×10^{-3}	3.3	388	21.851×10^{-3}	25.938	3049.680	3075.640	
									TOTAL: Q_s =	12,286.907	$\times 10^{-9}$	

TABLE 17 - Output Feedback Circuit Failure Rates

CIRCUIT	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFR	$C_{fr} \times 10^{9}$	$N \times C_{fr} \times 10^{9}$
0.120 Sec. Latch Circuit (8 Ckts.)	Unijunction Trans.	1	2N2422B	G.E.	0.20	0.20
	Transistor	1	2N3439	Motorola	0.20	0.20
	Transistor	1	2N3635	Motorola	0.20	0.20
	Diode	2	1N4608	G.E.	0.20	0.40
	Diodes	1	1N645	T.I.	0.15	0.15
	Diodes	2	1N4148	G.E.	0.15	0.30
	Diode	1	1N965B	T.I.	0.17	0.17
	Resistors	5	MF5C	Electra	0.10	0.50
	Resistor	1	MEB-T-0	IRC	0.10	0.10
	Resistor	1	AS-1	IRC	0.10	0.10
	Resistor	1	AS-1/2	IRC	0.10	0.10
	Capacitor	1	Neptune	San Fern	0.10	0.10
	Capacitor	1	X463UW	TRW	0.10	0.10
	Capacitor	1	K2R7J100KS	Kemet	0.50	0.50
	Permaloy Cores	1	80529-1/2D -MA	Magnetics	0.01	0.01
	Solder Joints	80			0.01	0.80
						3.93
ELB Clear Drivers (4 Ckts.)	Solder Joints	55			0.01	0.55
	Diodes	1	1N645	T.I.	0.15	0.15
	Diode	1	1N4608	G.E.	0.15	0.15
	Diode	2	1N4148	G.E.	0.15	0.30
	Zener Diode	1	1N965B	T.I.	0.17	0.17
	Zener Diode	1	1N746A	T.I.	0.17	0.17
	Resistors	8	MF5C	Electra	0.10	0.80
	Resistors	2	AS-1	IRC	0.10	0.20
	Capacitor	3	Neptune	San Fern.	0.10	0.30
	Capacitor	1	150D	Sprague	0.10	0.10
	Transistors	2	2N3499	Motorola	0.20	0.40
	Transistor	1	2N3635	Motorola	0.20	0.20
	Permaloy Core	1	80529-1/2 MA	Magnetics	0.01	0.01
	Unijunction Transistor	1	2N2422B	G.E.	0.20	0.20
						3.70
Set-Reset Output Latch (24 Ckts.)	Transistor	1	2N3947	Motorola	0.20	0.20
	Transistor	1	2N3499	Motorola	0.20	0.20
	Transistor	1	2N3635	Motorola	0.20	0.20
	Diodes	3	1N4608	G.E.	0.15	0.45
	Diodes	4	1N4148	G.E.	0.15	0.60
	Diodes	1	1N645	T.I.	0.15	0.15
	Resistors	6	MF5C	Electra	0.10	0.60
	Resistor	1	MEB-T-0	IRC	0.10	0.10
	Resistor	1	AS-1/2	IRC	0.10	0.10
	Resistor	2	AS-1	IRC	0.10	0.20
	Capacitors	2	Neptune	San Fern.	0.10	0.20
	Capacitors (Tant)	1	K2R7J100KS	Kemet	0.50	0.50
	Permaloy Cores	2	80529-1/2D -MA	Magnetics	0.01	0.20
	Solder Joints	67			0.01	0.67
						4.37

TABLE 18 - Output Circuits Unreliability

SUBSYSTEM: Individual Output Circuits

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $f_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\times 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET $\times 10^{-9}$
0.120 Second Latch	5200-209	2 - Series Pair	3.93	7.86	2.78×10^{-3}	3.3	388	21.851×10^{-3}	25.938	3049.680	3075.640	
Set/Reset Latch	5200-206 5200-207	1 - Series Pair	4.37	4.37	2.78×10^{-3}	3.3	388	12.149×10^{-3}	14.421	1695.560	1709.993	
Motor Switch Driver	5300-41	1 - Series Pair	2.65	2.65	2.78×10^{-3}	3.3	388	7.367×10^{-3}	8.745	1028.200	1036.953	
100 ma Switch	5200-205 5200-206	1 - Series Pair	2.25	2.25	2.78×10^{-3}	3.3	388	6.255×10^{-3}	7.425	873.000	880.686	
BECO	5200-205	1 - Series Pair	3.90	3.90	2.78×10^{-3}	3.3	388	10.842×10^{-3}	12.870	1513.200	1526.081	
Solenoid Driver	5300-41	1 - Series Pair	2.77	2.77	2.78×10^{-3}	3.3	388	7.700×10^{-3}	9.141	1074.760	1083.909	
Pyro Arming Circuit (PAC)	5300-41	1 - None, See Note 1	12.05	12.05	2.78×10^{-3}	3.3	388	33.499×10^{-3}	39.765	4675.400	4715.198	
0.5 Amp Switch	5200-41	1 - Series Pair	2.05	2.05	2.78×10^{-3}	3.3	388	5.699×10^{-3}	6.765	795.400	802.171	
Pyro Firing Circuit (PFC)	5200-203	1 - Series Pair	9.73	9.73	2.78×10^{-3}	3.3	388	27.049×10^{-3}	32.109	3775.240	3807.376	
Fuse Resistor		1 - None, See Note 1	0.10	0.1	2.78×10^{-3}	3.3	388	0.278×10^{-3}	0.330	38.800	39.130	
Pyro Power Conditioner	5300-41	1 - None, See Note 1	0.79	0.79	2.78×10^{-3}	3.3	388	2.196×10^{-3}	2.607	306.520	309.129	
SMJC	5500-41	1 - Series Pair	45.43	45.43	6.94×10^{-3}	158.4	0	315.284×10^{-3}	7196.112	0	7196.427	

TABLE 19 - Output Circuit Failure Rates

CIRCUITS	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
0.5 Amp Switch (2 Ckts)	Transistors	2	2N3499	Motorola	0.20	0.40
	Transistors	2	2N4999	Fairchild	0.20	0.40
	Diode	1	1N645	T.I.	0.15	0.15
	Resistors	2	MEB-T-0	IRC	0.10	0.20
	Resistors	4	MF5C	Electra	0.10	0.40
	Resistors	2	RH-10	Dale	0.10	0.20
	Solder Joints	30			0.01	0.30
						2.05
Pyro Arming Circuits (4 Ckts)	Inductor	1		Martin	10.00	10.00
	Transistors	1	2N4863	Solitron	0.20	0.20
	Transistor	1	2N5007	Fairchild	0.20	0.20
	Transistor	1	2N5579	Solitron	0.20	0.20
	Diode	1	1N4942	Unitrode	0.15	0.15
	Resistors	1	Rs-10	Dale	0.10	0.10
	Resistors	2	MF5C	Electra	0.10	0.20
	Resistor	1	RH-25	Dale	0.10	0.10
	Resistor	1	AS1	IRC	0.10	0.10
	Capacitor	1	K6R8-J100KS	Kemet	0.50	0.50
	Solder Joints	30			0.01	0.30
						12.05
Pyro Firing Circuits (28 Ckts)	Diodes	2	1N4608	G.E.	0.15	0.30
	SCR's	2	2N2325A	G.E.	2.0	4.0
	SCR's	2	2N684	G.E.	2.0	4.0
	Resistors	4	MF5C	Electra	0.10	.4
	Resistors	2	AS1	IRC	0.10	0.20
	Permaloy Cores	2	80529-1/2D MA	Magnetics	0.005	0.01
	Capacitors	2	Neptune	San Fern	0.10	0.20
	Capacitors	2	C062C104K 1 CA	Kemet	0.10	0.20
	Fuses	2 (Redund)			0.25×10^{-18}	
	Resistors	4	AS-1/2	IRC	0.1	.4
						9.71

TABLE 19 - Output Circuit Failure Rates (Con't)

CIRCUITS	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	$G_{fr} \times 10^{-9}$	$N \times G_{fr} \times 10^{-9}$
Solenoid Driver (4 Ckts)	Transistors	2	2N3499	Motorola	0.20	0.40
	Transistors	2	2N4031	Fairchild	0.20	0.40
	Transistors	2	2N4070	Solitron	0.20	0.40
	Diode	1	1N4942	Unitrode	0.15	0.15
	Resistors	2	As-1	IRC	0.10	0.20
	Resistors	6	MF5C	Electra	0.10	0.60
	Resistors	2	RH-5	Dale	0.10	0.20
	Solder Joints	42			0.01	0.42
						2.77
BECO Circuit (1 Ckt)	Resistors	6	MF5C	Electra	0.10	0.60
	Diode	1	1N645	T.I.	0.15	.15
	Transistor	2	2N3947	Motorola	0.20	.40
	Transistor	2	2N3499	Motorola	0.20	.40
	Transistor	2	2N4031	Fairchild	0.20	.40
	Resistor	4	MEB-T-0	IRC	0.10	0.40
	Transistor	2	RS-2A	Dale	0.20	0.40
	Solder Joints	50			0.01	0.50
						3.90
Motor Switch Driver Ckt (2 Ckts)	Transistors	2	2N4863	Solitron	0.20	0.40
	Transistors	2	2N5007	Fairchild	0.20	0.40
	Transistors	2	SDT8602	Solitron	0.20	0.40
	Diode	1	1N4942	Unitrode	0.15	0.15
	Resistors	4	MF5C	Electra	0.10	0.40
	Resistors	2	RH-25	Dale	0.10	0.20
	Resistors	2	RS-3A	Dale	0.10	0.20
	Resistor	2	RS-10	Dale	0.10	0.20
	Solder Joints	40			0.01	0.40
						2.75
Pyro Power Conditioner Circuit (6 Ckts.)	Solder Joints	8			0.01	0.08
	Diode	1	1N4942		0.15	0.10
	Resistor	1	MF5C	Electra	0.10	0.10
	Capacitor	1	K6R8J100KS	Kemet	0.50	0.50
	Core	1	1041T060-3E2A	Magnetics	0.01	0.01
						0.84
100 MA Output Switch	Transistors	2	2N3499	Motorola	0.20	0.40
	Transistors	2	2N4031	Fairchild	0.20	0.40
	Diode	1	1N645	T.I.	0.15	0.15
	Resistors	6	MF5C	Electra	0.10	0.60
	Resistors	2	MEB-T-0	IRC	0.10	0.20
	Resistors	2	RS-2A	Dale	0.10	0.20
	Solder Joints	30			0.01	0.30
						2.25

TABLE 19 - Output Circuit Failure Rates (Con't)

CIRCUITS	PIECE PART DESCRIPTION	QTY N	MFG. PART NUMBER	MFG.	G_{fr} x 10^{9}	N x G_{fr} x 10^{9}
SMJC	Diode	2	1N4141	G.E.	0.15	0.30
	Diode	2	1N756A	T.I.	0.15	0.30
	Diode	30	1N4608	G.E.	0.15	4.50
	Diode	4	1N645	T.I.	0.15	0.60
	Diode	2	1N961B	MOT	0.15	0.30
	Diode	2	VZ7720R	Unitrode	0.15	0.30
	Diode	3	VZ7850R	Unitrode	0.15	0.45
	Diode	4	1N4942	G.E.	0.15	0.60
	Diode	4	VZ7827L	Unitrode	0.15	0.60
	Resistors	12	AS-1	IRC	0.10	1.20
	Resistors	8	RS-5	Dale	0.10	0.80
	Resistors	2	AS-1/2	IRC	0.10	0.20
	Resistors	2	610	Dale	0.10	0.20
	Resistors	4	MEB-TO	IRC	0.10	0.40
	Resistors	84	MF4C	Electra	0.10	8.40
	Capacitors	14	Neptune	San Fern.	0.10	1.40
	Capacitors	10	150D	Sprague	0.10	1.00
	Capacitors	31	K-Series	Kemet	0.10	3.10
	Transistor	4	2N3947	Motorola	0.20	0.80
	Transistor	4	2N3635	Motorola	0.20	0.80
	Transistor	12	2N3499	Motorola	0.20	2.40
	Transistor	19	2N2221A	Motorola	0.20	3.80
	Transistor	8	2N5357	Motorola	0.20	1.60
	Transistor	8	2N4071	Fairchild	0.20	1.60
	Transistor	2	2N2907A	Fairchild	0.20	0 40
	Permoloy Core	18	80521-1/80 MA	Magnetics	0.01	0.18
	Inductor	18	3E2A	Ferrox Cube	0.10	1.80
	Solder Joints	760			0.01	7.60
						45.63

TABLE 20 - Unreliability of Output Switches Taken All Together

SUBSYSTEM: Output Switches

CIRCUIT	SCHEMATIC REFERENCE	QUANTITY AND TYPE OF REDUNDANCY	CIRCUIT FAILURE RATE $f_r \times 10^{-9}$	$Nf_r \times 10^{-9}$	TIME (HRS) = T			UNRELIABILITY				
					T x 1.0 OPERATE	T x 0.1 DORMANT	T x 0.25 NON OP.	OPERATE $\times 10^{-9}$	DORMANT $\times 10^{-9}$	NON OP. $\times 10^{-9}$	TOTAL $\times 10^{-9}$	REDUNDANT SET $\times 10^{-9}$
Solenoid Drivers	5300-41	4 - Series Pair	2.77	11.08	2.78×10^{-3}	3.3	388	30.802×10^{-3}	36.564	4299.040	4335.635	
Beco Circuit	5200-205	1 - Series Pair	3.90	3.90	2.78×10^{-3}	3.3	388	10.842×10^{-3}	12.890	1513.200	1526.081	
100 ma Output Switch	5200-205 (2 Ckts.) 5200-206 (2 Ckts.)	4 - Series Pair	2.25	9.00	2.78×10^{-3}	3.3	388	25.020×10^{-3}	29.700	3492.000	3521.725	
0.5 Amp Switch	5200-41	2 - Series Pair	2.05	4.10	2.78×10^{-3}	3.3	388	11.398×10^{-3}	13.530	1590.800	1604.341	
Motor Switch Driver	5300-41	2 - Series Pair	2.65	5.30	2.78×10^{-3}	3.3	388	14.734×10^{-3}	17.490	2056.400	2073.905	
0.120 Sec Latch Circuit	5200-209	8 - Series Pair	3.93	31.44	2.78×10^{-3}	3.3	388	87.403×10^{-3}	103.752	12,198.720	12,302.559	
Set-Reset Output Circuit	5200-206 (4 Ckts) 5200-207 (6 Ckts) Used three places	24 - Series Pair	4.37	104.88	2.78×10^{-3}	3.3	388	291.566×10^{-3}	346.104	40,693.440	41.039.836	
Pyro Power Conditioner Circuit	5300-41	6 - None, See Note 1	0.79	4.74	2.78×10^{-3}	3.3	388	13.177×10^{-3}	15.642	1839.120	1854.775	
Pyro Arming Circuit	5300-41	4 - None, See Note 1	12.05	48.20	2.78×10^{-3}	3.3	388	134.996×10^{-3}	159.060	18,701.600	18,860.794	
Pyro Firing Circuit	5200-203 Pages 1 - 6	28 - Series Pair	9.73	272.44	2.78×10^{-3}	3.3	388	757.383×10^{-3}	899.052	105706.720	106,606.529	
Resistors		45 - None, See Note 1	0.10	4.50	2.78×10^{-3}	3.3	388	12.510×10^{-3}	14.850	1746.000	1760.862	
ELR's Clear Drivers	5200-210	4 - Series Pair	3.70	14.80	2.78×10^{-3}	3.3	388	41.144×10^{-3}	48.840	5742.400	5791.281	
								TOTAL: 201.278323×10^{-6}				